President Truman had linked basic research with medical research in urging that greater emphasis be given to both. President Clinton spoke more broadly about an expanded commitment to discovery. In noting advances that had occurred in health research, he reminded his audience that these advances had depended upon progress in a wide range of science and engineering fields.

Both presidents spoke about the conditions required for the conduct of high quality research. But where President Truman focused on insulating research from short-term political issues, President Clinton stressed the need for a long-term, stable funding environment.

Perhaps the most telling contrast between the two speeches was with the specific emphases placed on the national objectives that research should serve. President Truman spoke at length about science, engineering, and national security, which was appropriate in a year in which Cold War tensions were markedly increasing. However, the national security theme was entirely absent from President Clinton's speech. Rather, his emphasis was on the economy, the environment, and quality of life. President Clinton also spoke about social responsibility, noting that "it is incumbent upon both scientists and public servants to ensure that science serves humanity always, and never the other way around." As an example, he referred to ethical problems associated with advances in biotechnology, a reference that President Truman could not possibly have made, since the structure of the DNA molecule, a prerequisite for modern, molecular-based biotechnology, was not to be discovered until 1953.

A good deal of President Truman's speech had to do with the obligations of the Federal Government toward science; in contrast, President Clinton emphasized the need for strengthened partnerships between science and other national sectors.

Both presidents touched on the public understanding of science: President Truman stressing the need for Americans to understand the special needs of research; President Clinton, the need to increase public awareness of the promise of science for the future.

Both Presidents Truman and Clinton concluded their remarks by looking toward futures that appeared very different in 1948 and 1998. President Truman's optimism was guarded, reflecting the still fresh memories of World War II and the uncertainties inherent in the deepening Cold War. In contrast, President Clinton's concluding remarks, which linked advances in knowledge with fundamental American values, were buoyant:

> I believe in what you do. And I believe in the people who do it. Most important, I believe in the promise of America, in the idea that we must always marry our newest advances and knowledge with our oldest values, and that when we do that, it's worked pretty well. That is what we must bring to the new century (Clinton 1998, 10).

Current Visions/Key Policy Documents

Science in the National Interest (1994)

The concept of a National Science Foundation began to take shape in 1944, near the end of a period in which national defense had dominated the Nation's agenda. Only a handful of visionaries in science and government understood that a well-articulated policy would be required in order for the Nation to derive optimum peacetime benefits from science and engineering.

As the 1990s opened, the United States faced the novel challenge of redefining its goals and priorities in the post-Cold War era. By then, the importance of science and engineering to the United States had been firmly established. Indeed, they had assumed a significance that the visionaries of the 1940s probably could not have anticipated. Implementation of the recommendations of *Science—The Endless Frontier* and *Science and Public Policy*, which their authors had assumed would occur in a time of peace, actually took place during a period when national defense considerations once again dominated the national agenda. Thus, with the Cold War over, it was useful to rearticulate the importance of science and engineering to the Nation and redefine their roles in an era in which social and economic concerns were destined to increase in importance relative to national security concerns.

The organization of science and technology within the Federal Government also evolved during the Cold War era in response to changing political, economic, and social circumstances. In May 1976, the U.S. Congress, with the encouragement of President Gerald R. Ford, created the Office of Science and Technology Policy (OSTP) within the Executive Office of the President, in effect reconstituting the Office of Science and Technology (OST), which had been created by President John F. Kennedy in 1962 and abolished by President Richard M. Nixon in 1973. The National Science and Technology Policy, Organization and Priorities Act of 1976 also provided for an external presidential committee analogous to PSAC, which President Nixon abolished at the time he abolished OST. This provision was finally implemented in 1989 when D. Allan Bromley, the President's Assistant for Science and Technology, convinced President George Bush to establish the President's Council of Advisors on Science and Technology. In a coordinated action, Bromley reinvigorated the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), a body consisting of the heads of all U.S. Government agencies with significant science and technology responsibilities. In 1993, President Clinton expanded the membership of FCCSET to include the heads of appropriate agencies within the Executive Office of the President, renaming it the National Science and Technology Council (NSTC).

In 1994, 50 years after Senator Harley Kilgore (D-WV) introduced his first bill to create a National Science Foundation and President Roosevelt requested advice from Vannevar Bush on the organization of science in the post-World War II era, the OSTP, in cooperation with the leading Federal science and technology agencies, convened a Forum on Science in the National Interest at NAS. Approximately 200 individuals from academia, industry, professional societies, and government participated in this event, suggesting the current breadth and reach of the U.S. science and engineering enterprise. *Science in the National Interest*, published in August 1994, summarized its results (Clinton and Gore 1994).

The organization of the Forum on Science in the National Interest, and the auspices under which it was convened, exemplified some of the important changes that had occurred in the status of science during the previous 50 years—in part as a result of recommendations made during the first period of transition. *Science—The Endless Frontier* was based upon the private deliberations of four *ad hoc* committees of prominent scientists convened to respond to a November 1944 letter from President Roosevelt. *Science and Public Policy* was prepared by a handful of mid-level staff within the Executive Office of the President, who consulted with colleagues in other Federal agencies and augmented their work by means of commissioned reports from nongovernment organizations. One of its recommendations was to establish a mechanism to bring important science policy issues to the attention of the highest levels of government.

OSTP, which convened the January 31–February 1, 1994, forum, was created to ensure that important science policy issues would, in fact, receive attention at the highest levels of the Federal Government. The fact that that agency even existed and was able to bring together approximately 200 individuals broadly representative of the Nation's science and engineering interests to articulate a vision for the future rather than relying on a group of select committees or staff within the Federal agencies suggests the changed social context in which science policy is viewed since the first time of transition.

Although the key documents of the 1940s argued persuasively that investments in science would yield significant benefits, they offered no specific, detailed examples. In contrast, *Science in the National Interest* included a variety of one-page, illustrated descriptions of benefits derived from those investments.

The most striking example of an advance that has occurred as a result of research investments was the simple, almost taken-for-granted fact that the entire text of *Science in the National Interest* was made available by way of the Internet, a development that even visionaries who predicted the bright future of information and communications technologies could not have dreamed of 50 years ago.

Science in the National Interest noted explicitly that its preparation did, in fact, occur during a time of transition. After paying its respects to the visionaries of the late 1940s, its second chapter, entitled "A Time of Transition," went on to articulate the new context in which national science policy must be formulated:

> The end of the Cold War has transformed international relationships and security needs. Highly competitive economies have emerged in Europe and Asia, putting new stresses on our private sector and on employment. The ongoing information revolution both enables and demands new ways of doing business. Our population diversity has increased, yielding new opportunities to build on a traditional American strength. Health and environmental responsibility present increasingly complex challenges, and the literacy standards for a productive and fulfilling role in twenty-first century society are expanding beyond the traditional "three R's" into science and technology (Clinton and Gore 1994, 3).

The report then suggested a framework for national science policy in terms of five goals regarded as essential to permit the U.S. scientific and engineering enterprise to address essential national objectives:

1. Maintain leadership across the frontiers of scientific knowledge.
2. Enhance connections between fundamental research and national goals.
3. Stimulate partnerships that promote investments in fundamental science and engineering and effective use of physical, human and financial resources.
4. Produce the finest scientists and engineers for the twenty-first century.
5. Raise scientific and technological literacy of all Americans (Clinton and Gore 1994, 7).

While stressing the desirability of reexamining and reshaping U.S. science policy, *Science in the National Interest* also emphasized that the core values that have enabled the Nation to achieve so much should be kept clearly in view. A strong commitment to investigator-initiated research and merit review based on evaluation by scientific peers should be regarded as foremost among those core values.

Unlocking Our Future (1998)

In October 1945, the U.S. Senate convened hearings on proposed legislation to create a National Science Foundation that involved a large number of witnesses from different sectors of the science and engineering enterprise, from education associations, BoB, and several old-line executive branch scientific bureaus. These and other, subsequent congressional hearings on issues such as control of nuclear energy or research in the military departments were instrumental in focusing widespread public attention on the importance of science and engineering in the postwar era. They also initiated a tradition of sustained congressional interest and attention to U.S. science policy. (See sidebar, "Congressional Science Policy Hearings and Studies.")

Following that tradition, on February 17, 1997, the Speaker of the House of Representatives acknowledged the need to reexamine the assumptions underlying U.S. science policy by requesting that the House Science Committee undertake a special study. Accordingly, Representative Vernon Ehlers (R-MI), a Ph.D. physicist and former college professor, was asked to lead a Committee study of "the current state of the Nation's science and technology policies" and to outline "a framework for an updated national science policy that can serve as a policy guide to the Committee, Congress, and the Nation" (U.S. House of Representatives Science Committee 1998, 6). The full Science Committee held seven hearings in order to obtain inputs for the study. In addition, Committee members and staff met with individuals and groups interested in reexamining U.S. science policy. Finally, the Committee took advantage of advances in information and communications technology by establishing a Web site to elicit comments and suggestions from the public, and the report itself was first made available to the public with the use of the Internet. The Committee successfully completed its work with the release of the report, entitled *Unlocking Our Future: Toward a New National Science Policy*—which was first made available to the public by way of the Internet—on September 24, 1998.

The Ehlers study was guided by a vision statement, which also provided the foundation for its report, namely, "The United States of America must maintain and improve its preeminent position in science and technology in order to advance human understanding of the universe and all it contains, and to improve the lives, health, and freedom of all peoples" (U.S. House of Representatives Science Committee 1998, 7).

Unlocking Our Future noted that three basic components of the scientific enterprise needed to be strengthened to ensure that this vision would be realized:

> First, …we must ensure that the well of scientific discovery does not run dry, by facilitating and encouraging advances in fundamental research;
>
> Second, we must see that … discoveries from this well must be drawn continually and applied to the development of new products or processes, to solutions for societal or environmental challenges, or simply used to establish the foundation for further discoveries;
>
> Finally, we must strengthen both the education we depend upon to produce the diverse array of people who draw from and replenish the well of discovery, as well as the lines of communication between scientists and engineers and the American people (U.S. House of Representatives Science Committee 1998, 12).

The report went on to discuss these components in considerable detail in terms of themes and issues that, along with those articulated in *Science in the National Interest*, provide a useful counterpoint to the themes and issues set forth in the key documents of the first time of transition.

Themes and Issues

Science in Service to Society

Because the objective of both *Science in the National Interest* and *Unlocking Our Future* was to reexamine science policy in a changing economic, political, and social context, both laid considerable emphasis on science in service to society. *Science in the National Interest* asserted that "We must reexamine and reshape our science policy both to sustain America's preeminence in science and to facilitate the role of science in the broader national interest" (Clinton and Gore 1994, 3).

Both reports emphasized the importance of research to health, economic prosperity, national security, environmental responsibility, and improved quality of life, as well as its contribution to the general culture. *Unlocking Our Future* also stressed the importance of science and engineering results to decisionmaking:

> We believe this role for science will take on increasing importance, particularly as we face difficult decisions related to the environment. Accomplishing this goal will require, among other things, the development of research agendas aimed at analyzing and resolving contentious issues, and will demand closer coordination among scientists, engineers, and policymakers (U.S. House of Representatives Science Committee 1998, 5).

Research Investments

Both reports acknowledged the indispensable role that Federal research investments play in maintaining the preeminence of the U.S. science and engineering enterprise and tacitly assumed that a broad bipartisan consensus to maintain that support would persist. According to *Science in the National Interest*,

> To fulfill our responsibility to future generations by ensuring that our children can compete in the global economy, we must invest in the scientific enterprise at a rate commensurate with its growing importance to society. That means we must provide physical infrastructure that facilitates world class research, including access to cutting-edge scientific instrumentation and to world-class information and communication systems (Clinton and Gore 1994, 1).

Unlocking Our Future emphasized that:

> Science—including understanding-driven research, targeted basic research, and mission-directed research—must be given the opportunity to thrive, as it is the precursor to new and better understanding, products and processes. The Federal investment in science has yielded stunning payoffs. It has spawned not only new products, but also entire industries (U.S. House of Representatives Science Committee 1998, 4).

Character of the Research System

Both reports agreed that, although adequate Federal support would continue to be essential to the science and engineering enterprise and would almost certainly continue to be forthcoming, its level would continue to be constrained. Therefore, it would be necessary to establish priorities for Federal support, taking into account the current and future character of the research system and its ability to contribute to societal goals. *Unlocking Our Future* stressed the need to take into account the entire Federal Government science and technology system, including the mission agencies, in determining priorities for Federal investments: "Research within Federal government agencies and departments ranges from purely basic knowledge-driven research, to targeted basic research, applied research and, in some cases, even product development" (U.S. House of Representatives Science Committee 1998, 16).

Congressional Science Policy Hearings and Studies

♦ **Hearings on National Science Foundation legislation (October–November 1945).** Joint hearings on two separate bills to create a National Science Foundation were held by the Senate Committee on Military Affairs starting on October 8, 1945, and extending to November 2 (England 1983). (See "Congressional Initiatives.") These hearings, which involved approximately 100 witnesses, provided the first occasion for a wide-ranging exploration of the status and future potential of science–government relations, including Federal support for research and education, and government organization for science. Representatives of *ad hoc* groups of nuclear physicists who were opposed to continued control of nuclear energy by the War Department used these hearings as the first opportunity to air their views in Congress, leading eventually to a decision of Senator Brien McMahon (D-CT) to introduce legislation (through another committee) that led to the creation of the Atomic Energy Commission on August 1, 1946. These hearings also resulted in a compromise bill to create a National Science Foundation, which passed the Senate in July 1946 but died when the House of Representatives declined to consider it.

♦ **Hearings on space policy (1957–58).** On November 25, 1957, six weeks after the Soviet Union launched Sputnik I on October 4, the Preparedness Subcommittee of the Senate Armed Services Committee convened hearings on U.S. space activities under the chairmanship of Senate Majority Leader Lyndon B. Johnson (D-TX) (U.S. House of Representatives 1980, 5–27). One immediate outcome was the establishment by the Senate of a Committee on Space Astronautics, chaired by Johnson, on February 6, 1958. The House followed suit on March 5 by establishing a Select Committee on Astronautics and Space Exploration chaired by House Majority Leader John McCormack (D-MA), with Representative Gerald R. Ford (R-MI) one of six minority members. Hearings before the Senate and House Committees resulted in the enactment of legislation to create the National Aeronautics and Space Administration on July 29, 1958. As a result of the impressive achievements of its Select Committee, the House also decided to establish a Standing Committee on Science and Astronautics on January 3, 1959.

♦ **Review of the National Science Foundation (1965–68).** In 1963, George P. Miller (D-CA), Chairman of the House Committee on Science and Astronautics, convinced his colleagues that, because of the increasing size and complexity of the Federal research system, the House should establish a mechanism to permit a more continuous, in-depth oversight of the system than had previously been necessary (U.S. House of Representatives 1980, 127–62). Accordingly, the Subcommittee on Science, Research, and Development, chaired by Emilio Q. Daddario (D-CT), was created on August 23, 1963. Among the subcommittee's first actions were to organize a series of periodic special seminars and panels with the objective of providing opportunities for members of Congress to meet and interact with members of the science and engineering communities; to request a detailed study from the Legislative Reference Service of the Library of Congress on the aids and tools available to Congress in the area of science and technology; and to send to the House floor legislation to create a Science Policy Research Division within the Library of Congress, which was enacted in 1964. In December 1965, the subcommittee received from this new unit a report titled *The National Science Foundation—Its Present and Its Future*, which provided the basis for a series of hearings designed to revise, update, and broaden the National Science Foundation Act of 1950. These hearings demonstrated widespread support for the Foundation, but also suggested that the agency had become a sufficiently significant component of the U.S. science and engineering enterprise to play a more active role than had been the case up to that time. Legislation enacted on July 18, 1968, amended the 1950 Act by requiring annual authorization for the agency; elevating its deputy director to the status of a presidential appointee; including the social sciences explicitly among those qualifying for National Science Foundation support; requiring that National Science Foundation analyze rather than simply gather and disseminate data on the condition of the science and engineering enterprise; and requiring that the National Science Board submit an annual report to the Congress through the President. (See "Congressional and Presidential Directives.")

In November–December 1969, the Subcommittee held a series of hearings that resulted, in 1972, in an Act to create the Office of Technology Assessment. Daddario was subsequently selected as the Office of Technology Assessment's first director.

♦ **Review of Federal policy and organization for science and technology (1973–76).** The Presidential Science Advisory System, established by President Eisenhower with the creation of the President's Science Advisory Committee and the appointment of James Killian as his full-time science advisor, and expanded with President Kennedy's creation of the Office of Science and Technology within the Executive Office of the President, enjoyed broad support in the Congress. After the President's Science Advisory Council and the Office of Science and Technology were abolished in January 1973, the House Subcommittee on Science, Research, and Development convened hearings, beginning in July of that year, on Federal policy and organization for science and technology.* Expanded hearings were held before the full parent Committee on Science and Technology in June–July 1975.** A majority of witnesses, including six former presidential science advisors, urged that Congress enact legislation to reestablish some type of presidential science advisory system. Parallel hearings leading to a similar conclusion were also held by the Subcommittee on the National Science Foundation of the Senate Committee on Labor and Public Welfare, chaired by Senator Edward M. Kennedy (D-MA). Gerald R. Ford, who became President following the resignation of Richard M. Nixon on August 8, 1975, was sympathetic to recreating such a system and directed Vice President Nelson A. Rockefeller to negotiate the matter with the Senate and House. These negotiations led to enactment, on May 11, 1976, of legislation creating the Office of Science and Technology Policy within the Executive Office of the President and articulating for the first time the consensus of Congress on the principles and elements of an adequate national science policy.***

♦ **House Science Policy Task Force study (1985–86).** In 1984, Congressman Don Fuqua (D-FL), Chairman of the House Science and Technology Committee, noted that Congress had not organized a broad review of national science policy since the Daddario Subcommittee hearings 20 years earlier. In July of that year, he convinced his colleagues to establish an *ad hoc* Science Policy Task Force within the Committee, which he also agreed to chair. During 1985 and 1986, the Fuqua task force held hearings on the entire range of science policy issues, including Federal support for research, research facilities in universities and Federal laboratories, science education, university–industry cooperation, the role of the public in setting the national research agenda, and international scientific cooperation, with an emphasis on cooperation in "big science." The task force also commissioned several special studies, including a collection of articles entitled *Reader on Expertise and Democratic Decision Making* and *A History of Science Policy in the United States, 1940–85*. The results of the two-year task force study were published in a multivolume set.

**U.S. Code Congressional and Administrative News, 94th Congress, Second Session,* vol. I, pp. 882–903.

**The Committee on Science and Astronautics was renamed the Committee on Science and Technology in January 1975.

***National Science and Technology Policy, Organization, and Priorities Act of 1976. Public Law 94-282, enacted May 11, 1976.

♦ **House Science Committee study (1997–98).** In February 1997, the Speaker of the House of Representatives requested that the House Science Committee,**** Chaired by James Sensenbrenner (R-WI), conduct a study to outline "a framework for an updated national science policy that can serve as a policy guide to the Committee, Congress, and the Nation." (See "Current Visions/Key Policy Documents.") Hearings and special meetings during the next two years under the guidance of Vernon Ehlers (R-MI) led, on September 24, 1998, to the release of a report entitled *Unlocking Our Future* (U.S. House of Representatives Science Committee 1998). Consisting of 51 pages of text, including four pages of summary recommendations, in addition to a four-page list of sources, the Ehlers report grouped its findings under four major headings: (I) Ensuring the Flow of New Ideas, (II) The Private Sector's Role in the Scientific Enterprise, (III) Ensuring that Technical Decisions Made by Government Bodies Are Founded in Sound Science, and (IV) Sustaining the Research Enterprise—The Importance of Education. In presentations to several scientific society meetings, Congressman Ehlers expressed the hope that the report would be only a first step in an ongoing process in which Congress would focus more actively on science policy, perhaps reviewing it every five years.

****The House Science and Technology Committee was renamed the House Science Committee in January 1995.

Unlocking Our Future also recognized the indispensable and increasingly important role of private industry both as supporter and performer of research. However, both reports emphasized the centrality of universities to the entire U.S. research enterprise. *Science in the National Interest* asserted that:

> A significant fraction of research, particularly fundamental research, is performed at academic institutions. This has multiple benefits. Research and education are linked in an extremely productive way. The intellectual freedom afforded academic researchers and the constant renewal brought by successive generations of inquisitive young minds stimulate the research enterprise (Clinton and Gore 1994, 7).

The increasing importance of multidisciplinary research, particularly as a basis for addressing national goals, was also emphasized by both reports.

Human Resources for Science and Engineering

Both reports assigned a high priority to human resources as an integral element of science policy. *Science in the National Interest* stated that "The challenges of the twenty-first century will place a high premium on sustained excellence in scientific research and education. We approach the future with a strong foundation" (Clinton and Gore 1994, 2). An adequate education for the 21st century requires greater flexibility, particularly at the graduate school level. *Unlocking Our Future* asserted that "While continuing to train scientists and engineers of unsurpassed quality, the higher education process should allow for better preparation of students who plan to seek careers outside of academia by increasing flexibility in graduate training programs" (U.S. House of Representatives Science Committee 1998, 42).

Both reports agreed that science education at all levels, including adequate science education for nonspecialists, was essential to the national interest. According to *Unlocking Our Future*, "Not only must we ensure that we continue to produce world-class scientists and engineers, we must also provide every citizen with an adequate grounding in science and math if we are to give them an opportunity to succeed in the technology-based world of tomorrow—a lifelong learning proposition" (U.S. House of Representatives Science Committee 1998, 5).

Partnerships

Preparation of both reports involved the active participation of individuals and groups with interests in the U.S. science and engineering enterprise. Appropriately, then, both emphasized the importance of partnerships in maintaining the vitality of the enterprise and strengthening its links with society. *Unlocking Our Future* took special note of the fact that:

> The science policy described herein outlines not only possible roles for Federal entities such as Congress and the Executive branch, but also implicit responsibilities of other important players in the research enterprise, such as States, universities and industry. We believe such a comprehensive approach is warranted given the highly interconnected relationships among the various players in the science and technology enterprise (U.S. House of Representatives Science Committee 1998, 11).

More broadly,

> Each member of society plays an important part in the scientific enterprise. Whether a chemist or a first-grade teacher, an aerospace engineer or machine shop worker, a patent lawyer or medical patient, we all should possess some degree of knowledge about, or familiarity with, science and technology if we are to exercise our individual roles effectively (U.S. House of Representatives Science Committee 1998, 36).

Science in the National Interest noted that:

> Science advances the national interest and improves our quality of life only as part of a larger enterprise. Today's science and technology enterprise is more like an ecosystem than a production line. Fundamental science and technological advances are interdependent, and the steps from fundamental science to the marketplace or to the clinic require healthy institutions and entrepreneurial spirit across society (Clinton and Gore 1994, 8).

Accountability

Because the overall objective of both reports was to examine the changing character of science and engineering in a rapidly changing social, economic, and political context, both laid considerable emphasis on public accountability. *Science in the National Interest* asserted the accountability theme simply and concisely at the outset: "The principal sponsors and beneficiaries of our scientific enterprise are the American people. Their continued support, rooted in the recognition of science as the foundation of a modern knowledge-based technological society, is essential" (Clinton and Gore 1994, 1). However, obtaining and maintaining broad public support, as *Unlocking Our Future* emphasized, requires the active engagement of individuals from several types of institution:

> Whether through better communication among scientists, journalists, and the public, increased recognition of the importance of mission-directed research, or methods to ensure that, by setting priorities, we reap ever greater returns on the research investment, strong ties between science and society are paramount. Re-forging those ties with the American people is perhaps the single most important challenge facing science and engineering in the near future (U.S. House of Representatives Science Committee 1998, 5).

International Dimensions

Both reports emphasized that cognizance of the international dimensions of research would be essential in formulating an adequate national science policy for the 21st century. *Unlocking Our Future* recognized that international collaborations are among the many types of partnership that individual scientists and engineers require to work effectively: "Although science is believed by many to be a largely individual endeavor, it is in fact often a collaborative effort. In forging collaborations, scientists often work without concern for international boundaries. Most international scientific collaborations take place on the level of individual scientists or laboratories" (U.S. House of Representatives Science Committee 1998, 21).

Science in the National Interest emphasized the importance of the international dimensions of science both to the

U.S. research enterprise and to U.S. national interests more broadly:

> The nature of science is international, and the free flow of people, ideas, and data is essential to the health of our scientific enterprise. Many of the scientific challenges, for example in health, environment, and food, are global in scope and require on-site cooperation in many other countries. In addition to scientific benefits, collaborative scientific and engineering projects bring Nations together thereby contributing to international understanding, good will, and sound decision-making worldwide (Clinton and Gore 1994, 8).

Advances in Science and Engineering

NSF funding of basic research across a broad range of disciplines as well as funding from other government agencies, industry, and academia in the United States and abroad has lead to many advances. Science and engineering breakthroughs have contributed to new capabilities in equipment that subsequently have enabled newer discoveries. It is not possible to review them all. The following discussion will be only illustrative in nature and will point to other ongoing efforts to identify and document such advances.

Central to the vision of the first transition period was the desirability of encouraging and facilitating partnerships among the three primary sectors of the U.S. research community: academia, industry, and government. Although the relationships among these sectors have changed considerably since that time, these partnerships have been essential to the major advances in all fields of science and engineering that have taken place during the past 50 years. These advances have led us to a better understanding of ourselves and the world around us. Increased understanding has, in turn, underlain the development of new products and processes, which have changed our everyday lives and the way we live them. Deeper understanding of specific aspects of the natural and human-influenced world has also demonstrated how little we know in many cases and suggested the need for new approaches to address important scientific and engineering problems. This finding has led to increased multidisciplinary research, international and intersectoral cooperation, and the creation of disciplines and whole industries (for example, information technology and biotechnology industries) that did not exist during the first transition period. Such advances have changed our lives, our economy, and our society in important and sometimes profound ways.[46]

The View by *Indicators*

Earlier editions of *Science and Engineering Indicators* reports have discussed important discoveries and advances. For example, the "Advances in Science and Engineering" chapter of *Science and Engineering Indicators – 1980* covered the following areas:

- Black Holes,
- Gravity Waves,
- The Sun,
- Cognitive Science in Mathematics and Education,
- Information Flow in Biological Systems,
- Catalysts and Chemical Engineering, and
- Communications and Electronics.

The *Science and Engineering Indicators – 1982* "Advances in Science and Engineering" chapter covered the following areas:

- Prime Numbers: Keys to the Code,
- The Pursuit of Fundamentality and Unity,
- The Science of Surfaces,
- Manmade Baskets for Artificial Enzymes,
- Opiate Peptides and Receptors,
- Helping Plants Fight Disease, and
- Exploring the Ocean Floor.

The *Science and Engineering Indicators – 1985* chapter entitled "Advances in Science and Engineering: The Role of Instrumentation" covered five case studies illustrating the important and synergistic roles that refinements in measuring and computing technologies play in undergirding and linking advances in science and engineering, as well as in developing new fields, processes, and products in academia and industry. The chapter highlighted the following areas:

- *Spectroscopy*—including a discussion of optical spectroscopy, mass spectroscopy, and nuclear magnetic resonance spectroscopy;
- *Lasers*—including discussions of applications in chemistry, measurement of fundamental standards, commercial applications, and biomedical applications;
- *Superconductivity*—including discussions of the fundamental process, the search for superconductors, applications, and ultra-high-field magnets;
- *Monoclonal Antibodies*—including the discovery of the technology, production of pure biochemical regents, studies of cell development, potential medical applications, and engineered monoclonal antibodies; and
- *Advanced Scientific Computing*—assisting scientists and engineers to test ideas on the forces moving the Earth's plates, track the path an electron takes within the magnetic fields of a neutron star, link a fragment of viral DNA to a human gene, watch plasmas undulating within fusion reactors yet to be built, form and reform digital clouds and monitor the formation of tornadoes, see galaxies born and watch their spiral arms take shape, set the clock at the (almost) very beginning and recreate the universe, begin

[46]See "100 Years of Innovation: A Photographic Journey," *Business Week*, Summer Special Issue 1999 for a remarkable essay of how science, technology, and innovation have changed our lives.